OUR ASTRONOMICAL COLUMN.

ENCKE'S COMET.—Of the three comets which are due to return this year—namely Encke's, Winnecke's and Wolf's, having periods of $3\frac{1}{3}$, $5\frac{1}{2}$, and nearly 7 years respectively—the first seems to have just been found, according to a Kiel telegram dated June 14. Prof. Hussey, telegraphing to Kiel, states that Mr. Coddington, on June 11, 9h. 13·1m. Lick mean time, found a comet, which he terms bright, in position R.A. 16h. 24m. 45·9s. and Declination (south) 25° 14′ 20″, the daily motions in these coordinates being 51′ and 36′ respectively. The comet thus lies in the constellation of Scorpio, a little to the north of the bright star α. A further telegram from Mr. John Tebbutt, dated June 14, states that this observer found the comet on June 12 in position R.A. 16h. 21m. and Declination (south) 25° 52′ at 9h. 22·9m. Lick mean time.

Much interest is attached to this comet, since its period is one of the shortest known. It was first seen in 1818 by that diligent observer Pons, on November 26, perihelion being passed in the following January. It was Encke, however, who undertook to investigate its motions, proving that its period extended over $3\frac{1}{3}$ years, and he predicted its return in 1822. At every succeeding return the comet has been observed, and it was even discovered that prior to 1818 it had been three times observed by Méchain, Caroline Herschel, and Thulis in the years 1786, 1795 and 1805. At its last return, in 1895, it was just visible to the naked eye at the time of its maximum brightness.

NEW DETERMINATION OF THE EARTH'S DENSITY.—Herr F. K. Ginzel, in the current number of *Himmel und Erde* (June, Heft 9), describes a new determination of the mean density of the earth by Dr. C. Braun, a former director of the observatory at Kalosca in Hungary. The apparatus used for this purpose was a torsion balance constructed by Dr. Braun himself, and from the description we learn that, excepting the suspension wires, glass globe, chronometer, chronograph, microscopes, and a few small parts, everything was made by himself. The method employed differed mainly from previous determinations in that the torsion balance was enclosed in a glass globe from which all air had been extracted. So complete was the vacuum that after four years no change could be detected. We leave our readers to gather from the above-mentioned source more details regarding the apparatus itself. The observations were begun in the year 1892, and two years later the computations were commenced. After all allowance had been made for corrections the final result gave for the value of the mean density of the earth 5·52765, which nearly corresponds with the best determination made by Prof. Boys. Herr Ginzel, in concluding his article, tells us that, disregarding the very high scientific importance that will be attached to this new determination, if we consider that Dr. Braun is considerably advanced in years, somewhat hard of hearing, and has not been blessed with good health during the last few years, and that he has been thinking over this problem for eleven years in addition to his usual official duties, all will agree in saying that this work is a rare proof of the scientific energy and ideal power of sacrifice for one man.

THE LARGE REFRACTORS OF THE WORLD.—The question of the efficiency of refractors of large apertures has recently been discussed in many articles, and the latest we owe to Prof. G. E. Hale, who deals in *Science* (May 13) with the frequently asked question, "Do large telescopes pay?" Prof. Hale points out the special kind of work to which refractors of large aperture should be employed, and shows that when used by a skilled observer very important work can be accomplished which would be impossible with a small aperture. An instrument, say, of forty inches aperture is more advantageous than one of ten inches, in that, first, it has the power of giving much brighter images, thus rendering faint stars visible. It can, secondly, give an image of a celestial body of measurable dimensions four times as large as that given by a lens of one-fourth its aperture and focal length; and, thirdly, its capacity of rendering visible, as separate objects, the components of very close double stars or minute markings upon the surface of a planet or satellite. Prof. Hale concludes that all the money and time and labour are well spent on refractors of large aperture, and he suggests that further sums might well be expended, particularly in the southern hemisphere, in the establishment of still more powerful instruments.

A propos of large refractors, a fairly complete list of existing large refracting telescopes appears in the current number of the *Observatory* (June), in which are given details concerning the aperture, focal length, location, maker, and date of erection of the various instruments. America comes first as regards the number of instruments and largest size of aperture, followed by France, England and Germany in the order respectively of the number of refractors exceeding 13·4 inches.

THE LEEDS ASTRONOMICAL SOCIETY.—It is always with pleasure that we refer to scientific societies for the promotion and extension of astronomical knowledge, when we know that they are doing useful work in this respect. The *Journal* (No. 5) of the Leeds Astronomical Society for the year 1897 is a good example of the interest displayed by its members in fostering astronomy, and during the past year many interesting papers were read at their meetings. Among these may be mentioned that on the nebular origin of our solar system, by Mr. Barbour, who refers to and extends the significant relationships between the distances and masses of the four superior planets suggested by Mr. Sutcliffe of Bombay, and previously referred to in this column (vol. lvi. p. 424). Other papers read had for their subjects the heat of the sun, the planet Venus, orientation of Egyptian temples, density of the earth, &c. This number contains also an excellent likeness of the retiring president, Mr. Washington Teasdale.

RECENT EXPERIMENTS ON CERTAIN OF THE CHEMICAL ELEMENTS IN RELATION TO HEAT.[1]

THE discovery that different substances have different capacities for heat is usually attributed to Irvine, but there can be no doubt that Black, Crawford, and others contributed to the establishment of the idea. The fact that equal weights of different substances in cooling down through the same number of degrees give out different amounts of heat, may be illustrated by the well-known experiment in which a cake of wax is penetrated with different degrees of rapidity by balls of different metals heated to the same temperature. But for the quantitative estimation of the different amounts of heat thus taken up and given out again, the physicist must resort to other forms of experiment, each of which presents difficulties of its own. Broadly speaking, three principal methods have been used in the past for the estimation of "specific heats." The first is based upon the observation of the exact change of temperature produced in a known mass of water by mixing with it a known weight of the substance previously at a definite temperature above or below that of the water. The second consists in determining the quantity of ice melted when the heated body is brought into contact with it in such a way that no heat from any other source can reach the ice. And the third method consists in observing the rate at which the heated body falls through a definite range of temperature when suspended in a vacuous space.

The process of intermixture with water was used by the earlier experimenters in the last century, and some of the best results extant have been obtained by this process, which, however, is not so easy as it appears when the highest degree of accuracy is desired.

Lavoisier and Laplace in 1780 devised the ice calorimeter which bears their name, and in a most interesting memoir, which is reprinted among Lavoisier's works, they show that they were familiar with the idea which in modern times is known as the principle of the conservation of energy. In this memoir they give the results of experiments in which the specific heats of iron, mercury, and a few other substances are estimated with a very tolerable approach to accuracy. Although many of the metals were known to them, it would not have been possible, had they persisted in this work, to make the discovery which was reserved for Dulong and Petit thirty-five years later, for the atomic theory had not been conceived and no atomic weights had been determined.

Dulong and Petit (*Ann. Chim.*, 1817, vii. p. 144) seem to have used at first the method of mixtures, and to have found by direct experiment that the specific heat of solids (metals and glass) increases with the temperature. They also studied (after Leslie) the laws of cooling of bodies; and two years after the publication of their first paper on the subject, they (Petit and Dulong, *sic*) arrived at the remarkable general expression which is associated with their names (*Ann. Chim.*, 1819, x. 395).

---

[1] A discourse delivered at the Royal Institution, Friday evening, May 13, by Prof. W. A. Tilden, D.Sc., F.R.S.

After pointing out that all the results of previous experiments, except those of Lavoisier and Laplace, are extremely incorrect, they describe their results obtained by the method of cooling, conducted with many precautions to avoid error.

COPY OF TABLE BY DULONG AND PETIT (*Ann. Chim. Phys.*, 1819, x. 403).

	Specific heats	Atomic weights (o = 1)	Atomic weight × specific heat
Bismuth ...	... ·0288	13·30	·3830
Lead ..	... ·0293	12·95	·3794
Gold ...	... ·0298	12·43	·3704
Platinum ...	... ·0314	11·16	·3740
Tin ...	... ·0514	7·35	·3779
Silver ...	... ·0557	6·75	·3759
Zinc ...	... ·0927	4·03	·3736
Tellurium	... ·0912	4·03	·3675
Copper ...	... ·0949	3 957	·3755
Nickel ...	... ·1035	3·69	·3819
Iron ...	... ·1100	3·392	·3731
Cobalt ...	... ·1498	2·46	·3685
Sulphur ...	... ·1880	2·011	·3780

The statement of the law is best given in the words of the authors (p. 405):

"Les atomes de tous les corps simples ont exactement la même capacité pour la chaleur."

Here the question rested till resumed, many years later (1840), by Regnault, who in his first memoir (*Ann. Chim.*, 73, 5) points out the difficulties which attended the acceptance of the statement of Petit and Dulong in the form in which they gave it. He then discusses the three principal experimental methods, viz. (1) fusion of ice, (2) mixture, (3) cooling, and decides in favour of the second, which he used throughout his researches. The general form of the apparatus used by the great physicist has been a model for the guidance of successive experimentalists since his time.

Another quarter of a century elapsed before the question of the specific heat of the elements was resumed by Hermann Kopp. His results were communicated to the Royal Society, and are embodied in a paper printed in the *Philosophical Transactions* for 1865. After reviewing the work of his predecessors, he describes a process by which he has made a large number of estimations of specific heat, not only of elements but of compounds of all kinds in the solid state. Concerning his own process, however, he remarks that "the method as I have used it has by no means the accuracy of that of Regnault" (p. 84).

In 1870 Bunsen introduced his well-known ice-calorimeter. This is an instrument in which the amount of ice melted by the heated body is not measured by collecting and weighing the water formed, but by observing the contraction which ensues when the ice melts, contained in a vessel of special form. The results obtained by Bunsen himself are uniformly slightly lower than those of Regnault for the same elements.

Since that time experiments have been made by Weber, Dewar, Humpidge, and others in connection especially with the influence of temperature in particular cases.

Setting aside the elements carbon, boron, silicon and beryllium, as providing an entirely separate problem, the question is whether the law of Dulong and Petit is strictly valid when applied to the metals. Kopp, in his discussion of the subject, came to the conclusion that it is not; but the grounds for this conclusion are unsatisfactory, since neither the atomic weights nor the specific heats were at that time known with sufficient accuracy.

It has been customary to assume that the divergencies from the constant value of the product, At. Wt. × Sp. Ht., are due partly to the fact that at the temperature at which specific heats are usually determined, the different elements stand in very different relations to their point of fusion; thus lead at the temperature of boiling water is much nearer to its melting-point than iron. It has also been attributed to temporary or allotropic conditions of the elements. As to the relation to melting-point, the specific heats of atomic weight seem to be practically the same in separate metals and alloys of the same which melt at far lower temperatures. For example, the atomic heat of cadmium is 6·35, of bismuth 6·47, of tin 6·63, and of lead 6·50; while the mean atomic heat in alloys of bismuth with tin and lead with tin, ranges from 6·40 to 6·66 (Regnault), which is practically the same.

Again, while the melting-point of platinum is at a white heat, and it becomes plastic at a low red heat, the specific heat at this lower temperature is very little less. Many other metals change considerably in properties at temperatures far removed from their melting-points, without substantial change in their capacity for heat.

As to allotropy it is a phenomenon which is comparatively rare among metals, and in the marked cases in which it occurs we have no information as to the value of the specific heats in the several varieties (such as the two varieties of antimony and the silver zinc alloy of Heycock and Neville), and they may be left out of account. Bunsen compared the so-called allotropic tin obtained by exposing the metal to cold for a long time, and found it 0545 against ·0559 for the ordinary kind (*Pogg. Ann.*, 141, 27). In dimorphous substances, such as arragonite and calcite, there is often no difference. Regnault found for these two minerals ·2086 and ·2085 respectively.

The differences between metals hammered and annealed, hard and soft, were also found by Regnault to be very small (*Ann. Chim.* [3] ix.):—

Hard steel	·1175	Same, softened ...	·1165
Hard bronze	·0858	Same, softened ...	·0862

Kopp came to the conclusion, *first*, that each element in the solid state and at a sufficient distance from its melting-point has *one* specific or atomic heat which varies only slightly with physical conditions; and, *secondly*, that each element has essentially the same specific or atomic heat in compounds as it has in the free state. This last is practically identical with the statement which is known as Neumann's law. With Kopp's conclusions I agree, but from some of Regnault's results, coupled with my own, the effect of *small* quantities of carbon and, perhaps, of sulphur upon the specific heats of metals is greater than has been supposed.

If we take the results of Regnault and of Kopp, and combine them with the most accurately known atomic weights, the products are still not constant.

ATOMIC WEIGHTS MOST ACCURATELY KNOWN (1897), COMBINED WITH SPECIFIC HEATS.

	A.W. (H = 1)	S. H. Regnault	S. H. Kopp	At. Ht. Regnault	At. Ht. Kopp
Copper	63·12	·09515	·0930	6·01	5·87
Gold	195·74	·03244	—	6·35	—
Iron	55·60	·11379	·1120	6·33	6·23
Lead	205·36	·03140	·0315	6·45	6·47
Mercury liq.	198 49	·03332	—	6·61	—
− 78° to + 10° sol.	198·49	·03192	—	6·34	—
Silver	107·11	·05701	·0560	6·11	6 00
Iodine	125 89	·05412	—	6·81	—

The law of Dulong and Petit is therefore only an approximation, but this may perhaps be due to impurity in the materials used. That is the problem which I have endeavoured to solve.

The introduction of a new method of calorimetry by Prof. J. Joly, and the excellent results obtained by the author in the use of the differential form of his instrument (*Proc. R. S.*, 47, 241), led me to think that with due attention to various precautions, such as exact observation of the temperatures and practice in determining the moment at which the increase of weight due to condensation is completed, results of considerable accuracy might be obtained.

The problem is to find two elements very closely similar in density and melting-point which can be obtained in a state of purity, and then to determine with the utmost possible accuracy the specific heat of each under the same conditions. The two metals cobalt and nickel were selected for the purpose. They were examined by Regnault, but the metals he used were very impure.

The cobalt employed in my experiments was prepared by myself. For the nickel I am indebted to Dr. L. Mond. Both were undoubtedly much more nearly pure than any metal available in Regnault's time. The results obtained are as follows:—

Specific Heats of Cobalt and Nickel. Pure fused.

Cobalt S.G. $\frac{21^\circ}{4^\circ}$ 8·718	Nickel S.G. $\frac{21}{4^\circ}$ 8·790
·10310	
·10378	
·10310	·10953
·10355	·10910
·10373	·10930
·10362	
Arith. mean ·10348	·10931
Atomic heat	?

Further experiments will be made, because a single well-established case of this kind is sufficient to decide the question. Already, however, I feel certain that Kopp's conclusion is right, and that the law of Dulong and Petit, even for the metals, is an approximation only, and cannot be expressed in the words of the discoverers. For although the exact values of the atomic weights of these two elements are not known, it is certain that they are not so far apart as would be implied by these values for the specific heats, even assuming that the value for nickel is, as I believe, slightly too high.

Two other examples of somewhat similar kind are shown by gold and platinum, copper and iron.

Specific Heats of Gold and Platinum. Pure fused.

Gold S.G. $\frac{18^\circ}{18^\circ}$ 19·227	Platinum S.G. $\frac{18^\circ}{18^\circ}$ 21·323
·03052	·03147
·03017	·03150
·03035	·03144
Arith. mean ·03035	·03147
Atomic heat 5·94	6·05

Specific Heats of Copper and Iron. Fused.

Copper (pure) S.G. $\frac{20^\circ}{20^\circ}$ 8·522	Iron S.G. $\frac{15^\circ}{15^\circ}$ 7·745
·09248	Contains ·01 °/o C.
·09241	·11022
·09205	·11037
·09234	
Arith. mean ·09232	Arith. mean ·11030
Atomic heat 5·83	6·13

For the gold I naturally applied to my colleague Prof. Roberts-Austen. The platinum I prepared from ordinary foil by re-solution, and reprecipitation as ammonic chloride, &c. Both metals were fused into buttons before use. The atomic heats come closer together than those of cobalt and nickel.

Copper and iron differ considerably in melting-point, but both at the temperature of 100° are far removed from even incipient fusion. The copper was prepared from pure sulphate by electrolysis, the iron by reduction of pure oxide in pure hydrogen. Notwithstanding all our care, it was disappointing to find it contained ·01 per cent. of carbon, the source of which I am at a loss to explain. This iron is purer than any examined by Regnault or Kopp.

The differences observed between Co and Ni, and between Au and Pt, are manifestly not due to allotropy or to differences of melting-point, which in these cases can have no effect on the result.

So large a difference must be due to peculiarities inherent in the atoms themselves, and differences of atomic heat are to a certain extent comparable with the differences observed in other physical properties which, like specific volume, specific refraction, &c., are approximately additive.

If we try to think what is going on in the interior of a mass of solid when it is heated, the work done is expended not only in setting the atoms into that kind of vibration which corresponds to rise of temperature—that is, it makes them hotter—but partly in separating the molecules or physical units from one another (= expansion), and partly in doing *internal* work of some kind, the nature of which is not known. A difference between metals and non-metals has been brought out by the researches of Heycock and Neville, who find that metals dissolved in metals are generally monatomic; whereas it is generally admitted that iodine, sulphur and phosphorus in solution are polyatomic. It is, moreover, remarkable that although in respect to specific heat each element in a solid seems to be independent of the rest with which it is associated, when the separate elements are dispersed in vapour some rise in separate atoms like mercury, some in groups of atoms I_2, S_6, As_4, P_4, and these groups, as the temperature is raised, are simplified with very varying degrees of readiness.

Sulphur vapour, for example, diminishes in density from 7·9 at 468°, to 4·7 at 606° (Biltz), that is, from about S_7 to S_4, and iodine from density 8·8 at 253°, to 5·6 at 1570° (V. Meyer), that is, from about I_2 to $\frac{2}{3}$ I_2, but the dissociation of As_4 and P_4 begins only at much higher temperatures, while with mercury there is no corresponding change.

But, although these groups are taken as the chemical molecules, the physical unit in the solid is certainly the atom, whether united by combination or mere mixture.

The two metals, cobalt and nickel, with which I began my inquiry, have nearly the same atomic weight, but they differ from each other remarkably in chemical properties. For example, nickel forms a compound with carbonic oxide; on the other hand, cobalt produces many remarkable ammoniacal compounds, to which there is nothing corresponding among the compounds of nickel.

Having put aside the common excuses for the observed divergencies from the law of Dulong and Petit, we are compelled to look round for some other hypothesis.

The constitution of carbon compounds is now explained by a hypothesis concerning the configuration of the carbon atom introduced by Van t' Hoff and Le Bel twenty-five years ago, and which is now accepted by the whole chemical world. It seems not unreasonable to apply a similar hypothesis to the explanation of those cases of isomerism which have been observed in certain compounds of the metals, notably chromium, cobalt, and platinum. This has already been done by Prof. Werner of Zürich. Of course, as there is no asymmetry, there are no optical differences in the pairs of compounds thus represented. If the constitution of compounds can be safely explained by such hypothesis, this implies peculiarities in the configuration of the individual constituent metals around which the various radicles are grouped in such compounds, and hence peculiarities in the behaviour of such metals in the elemental form may possibly be accounted for. For the atom of cobalt, Prof. Werner employs the figure of the regular octahedron. For nickel, therefore, which differs from cobalt, especially in yielding the remarkable carbonyl compound discovered by Mond, and by not yielding ammines like those of cobalt, and in other ways, a different figure must be chosen. This, however, is for the present a matter of pure speculation.

SCIENCE IN THE THEATRE.

THE assimilation of nature on the stage! To what extent is assimilation possible, and what are the necessary methods and appliances for obtaining a satisfactory assimilation? This practically was the subject of a very valuable paper prepared for the Society of Arts by Mr. Edwin O. Sachs, the architect, which led to an animated discussion at the crowded meeting before which it was read. The title of Mr. Sachs' paper, it is true, was briefly "Stage Mechanism," but he went far beyond the mere description of the various appliances that can be used for obtaining certain scenic effects, and, more especially in his introduction, treated the subject on broad lines.

Though the presentation of drama and opera with some attempt at realistic surroundings is now accepted as a matter of course in all civilised countries, it can but rarely be said that the attempts are successful. In fact, only of recent years has the London manager been able to give us the presentation of indoor scenes with some claim to merit, and this only by building up his various scenes piecemeal in a most cumbersome way, which is all that is possible where the changes of scene are few and the "run" long. As to the presentation of scenes out of doors, the London manager has most lamentably failed, no matter how well painted individual canvases may have been, or how tricky the arrangements of individual scenic effects. A sky that looks like so much blue calico hanging on a wash-line, a horizon with angles, a tree that looks like a piece of card-board, or a moon which suddenly rushes into the sky and then remains stationary, are all anomalies, and form only a few of the innumerable details which tend to make a scene incongruous.

Now according to Mr. Sachs, who fully recognises the attempts that have been made from time to time by Sir Henry Irving, Mr. Beerbohm Tree, Sir Augustus Harris, and others